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ABSTRACT

MICROPIK is a multiple-alternatives, criterion-referenced model for evaluating CAI (computer-assisted instruction) software and microcomputer hardware against selected curricular objectives. The model provides decision-modeling control over diverse interactive patterns that occur when computer hardware, courseware, and instructional objectives are compared for their value in facilitating future instructional computing needs at the district level. Using a partitioned trimatrix modeling structure, the complex interactions between hardware costs, software quality, and curriculum requirements are cross-compared, and the best instructional computing system identified. While computer modeling is somewhat complex, district-level considerations for acquisition of computer equipment and materials for educational purposes warrant a meticulous approach to decision-making, on account of the wide array of hardware and courseware becoming available on the market. Four pages of selected readings and references are included. (Author/TE)

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THE MICROPIK™ MODEL: CHOOSING COMPUTER SYSTEMS FOR INSTRUCTION

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ABSTRACT

Choosing the best hardware and courseware for instructional computing at the district level requires computer modeling control over curricular objective interaction and priority.

SUMMARY

MICROPIK™ provides decision modeling control over diverse interactive patterns which occur when computer hardware, courseware and instructional objectives are compared for their value in best facilitating future instructional computing needs at the district level. Using a partitioned, tri-matrix modeling structure the complex interactions between hardware costs, software quality, and curriculum requirements are cross-compared, and the best instructional computing system identified. While computer modeling is somewhat complex, district level considerations for computer equipment and materials acquisitions to best facilitate district missions related to teaching and student learning, and the wide array of hardware and courseware becoming market-available presently, warrant such a meticulous approach to a complicated decision setting.

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D E D I C A T I O N

This project is dedicated to all those professionals who yet aspire to what educational planning and program evaluation could be, not necessarily content to allow it to remain what it has become, but seek new techniques for dealing with not-so-new problems related to strategic planning and tactical deployment.

This work is also dedicated to that subset of educational professions who stand in our way, for without them, we might never have the drive and determination to seek new methods, and then validate these innovative processes as rigorously as we do to prove our point.

Original development of this project was completed pursuant to Contract No. 400-80-0105 of the National Institute of Education, U.S.A., and under agreement with the Northwest Regional Educational Laboratory in Portland, Oregon (June 1982). All subsequent work in this area does not fall under the auspices of the NWREL or NIE, and is the sole property of the Author.

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INTRODUCTION

There has been little doubt that the approach of both public and private education, in regards to the determination of instructional computing needs and the acquisition of such equipment and materials which would satisfy those needs, has been less than successful in both (1) understanding what computers might do in the classroom to promote learning, and how, and (2) identifying the best mix of software and hardware elements to provide an optimized, computer assisted learning environment for both student and teacher.

Initially, classroom teachers and school administrators understood little themselves about the capabilities of the computer -- a situation which extenuated the documented misuses and abuses of computers in the classroom. As such knowledge increased, however, teachers and administrators were lured into purchasing hardware (first) because of vendor discounts, software (second) since the machines were now available, and then (third) trying to decide how best to operationalize such equipment and material resources for classroom use. Unfortunately, at least for those professionals who knew enough of instructional computing to recognize the problems eventually, teachers and administrators found that the sequential 'hardware, then software, then uses' approach to instructional computing initiation has serious flaws for effective instructional program development and implementation. Presently, another problem has arisen which is no less severe than its predecessors -- that of knowing how to evaluate properly software and hardware to assure that instructional computing procedures are sound, reliable and valid as instructional intervention.

While several dozen approaches to courseware (viz. software for instructional applications) evaluation have been marketed in recent months via so-called "professional teacher journals" which deal entirely with instructional computing, little has been said concerning how evaluation results can be effectively and appropriately utilized to compare and contrast alternative courseware packages, the machines on which these packages are executable, and the specific instructional objectives and classroom activities of the curriculum. Certainly, no author has addressed the answer to the question(s)

How can I incorporate what I know about (1) my curricular needs, (2) the needs of my students, (3) the capabilities of instructional computing, and (4) and the courseware and hardware which support such computer assisted strategies -- to determine:

A. which courseware packages best suit my individual needs, both curricularly and student based, and the extent to which such packages complement each other;

B. which hardware unit(s) best support the implementation of these courseware packages, and the degree to which additional peripheral equipment is required;

C. which instructional objectives, and their underlying classroom activities are best operationalized via this courseware/hardware system, the extent to which these objective-based activities are supported, and the degree to which they are not; and,

D. which mix-match(es) of objectives-courseware-hardware elements best prepares a computer assisted environment for teaching and student learning, based upon other types of criterion based constraints.

A first attempt at developing a model which might solve the above dilemma was authored in 1982 (see: MICROPIK: A Multiple-Alternatives, Criterion-Referenced Decisioning Model for Evaluating CAI Software and Microcomputer Hardware Against Selected Curriculum Instructional Objectives). Since that time, continued research in the area of hierarchical decision modeling has provided a clearer understanding of the roles for mathematical models, computer simulation and multiple alternatives modeling™ in the generation of solutions for many of the complext problems facing education today. The subject of this paper, the MICROPIK™ modeling formulation illustrates a highly structured approach to deciding which courseware and hardware matches best support which instructional objectives of the classroom teacher.

MICROPIK™ is a very complex technique itself, and is not without its own limitations and cautions. However, the theortical framework and practical experiences which support its development sustains its potential applicability for use at the district and state level.

This paper is an update of the 1982 MICROPIK™ formulation, and serves to extend the work initially accomplished with the 1982 report to the Northwest Regional Education Laboratory in Portland, Oregon. Copies of the original paper are available by request to Dr. Nick Smith, Director, Research on Evaluation Project, NWREL.

DECISION MODELING AND HIERARCHICAL SIMULATIONS

The 'making of a decision' involves a series of events, some performed simultaneously, which typically require the decisionmaker to compare and contrast multiple alternative actions, evaluating each potential alternative through the use of multivariate criteria, and where the final selection of a 'best decision' represents a choice which (1) fits the parameters of the decisioning environment and (2) exists as the most optimal decision available. The ability to compare and contrast alternatives, based upon specific references to system parameters and environmental needs, is the mission of decision modeling.

Decisions, however, are seldom so discrete or individually distinct as to portray specifically and exactly 'what is to happen' as the result of such a potential decision being selected as optimal. For example, the modeling of decisionmaking in the case of school closures (see: Modeling Elementary and Secondary School Closures Through MAM™ (1984)) requires not only that school sites be targeted for either operational continuance or discontinuance, but also that each site have the parameters of continuance/discontinuance specifically defined (e.g. close with sale versus close with mothball, etc.). Similarly, the modeling of decisionmaking in the case of budget reductions at the university level (see: Reducing Higher Education Budgets Through Multiple Alternatives Modeling™ (1984)) requires that, for each program budget targeted for a future budgeting decrease, the specific percentage amount of that decrease be analyzed and output to the decisionmaker. Alternatively, if a program budget is to receive an increase, then the amount of that increase must be specified. The ability to perform decisionmaking at several levels of the decisional environment, viz. to specify which alternatives should be implemented and the extent to which such alternatives must be executed, is called hierarchical decisioning.

These processes of comparing, contrasting, evaluating and selecting are all part of a decisional modeling strategy, called simulation. To have the ability to simulate alternate actions, and thereby gain valuable information regarding likely actions which will positively influence the environment of the identified problem, the decisonmaker needs to understand a number of issues related to decision modeling and hierarchical simulations.

Decisions as Discrete Events. Any potential decision under evaluation necessarily assumes that the proposed action(s) is discrete, viz. will provide specific direction(s) to the decisionmaker if selected as the final decision for implementation. Multiple discrete events which are to be evaluated for their comparative value as the final decision must (or at least, should) share a number of qualities, the most important of which are mutual exclusiveness and collective exhaustiveness. Generally speaking, these qualities address the need that alternative actions, as potential decisions, be unique (i.e. not redundant) and indicative of all possible actions available to the decisioner, respectively.

The Hierarchical Decision. While not all decisionmaking requires a hierarchical approach to modeling, it is nevertheless true that most alternative actions are initially identified through a 'top-down' (i.e. hierarchical) delineation approach of (1) problem recognition, (2) needs identification, (3) parameters specification, (4) alternative actions evaluation, and (5) final decision selection. Each discrete decision not only impacts the organization, but also affects the potential for other discrete decisions to be chosen subsequently as future action-oriented needs. The hierarchical decision allows educational planners to view and interpret (1) specific actions which are suggested by the modeling framework, and (2) the policy of the organization within which such decisions are (or are not) in compliance.

The Concept of Decision Modeling. Decision modeling fosters the belief that highly fluid, transactional environments require a structured approach to the evaluation of alternate actions, and the identification of the best strategic and/or tactical action(s) from these alternatives. Modeling means to construct

a facsimile of those content and process characteristics of an environment through which alternative actions can be compared and contrasted by means of their 'predictable' effects upon the environment modeled. From such modeling episodes, likely effects can also be compared, and those actions which produce the most desirable consequences can be identified as optimal decisions.

The Function of Simulation. To simulate is to test; that is, simulation is the technique of alternative actions' comparision and contrasting which allows the functional use of the model (environmental facsimile) previously constructed. Typically, although this does not mean that qualitative models do not or can not exist, both the model and the simulation technique are quantitative in design, and therefore require mathematical processes which effectuate the desired simulation. These mathematical processes must satisfactorily (viz. validly and reliably) utilize the criterion parameters of the model in order to understand 'how a potential alternative action might fit' with these expressed needs of the environment determined through problem delineation.

ELEMENTAL CHARACTERISTICS OF HIERARCHICAL MODELING

The decisional modeling of hierarchical alternatives assumes that a number of factors or conditions exist which warrant the model builder's attention. Such factors include, but may not be limited to (depending upon the specific modeling episode): (1) the type of lower order alternatives in the hierarchy, (2) the relationship(s) of these lower order alternatives to other lower order alternatives, and (3) the structure of the simulation model within which these alternatives will be tested for both feasibility (viz. whether each alternative is reasonable based upon the parameters of the decisional environment) and optimality (viz. the extent to which such feasible alternatives compare among themselves).

Fixed Versus Variable Hierarchies. A fixed-alternatives hierarchy simply means that the same lower order alternatives, by type and number, are available to each of the higher order alternatives being modeled for simulation. For example, the school closure model allows each school site to be evaluated for

the potential feasibility of the action, 'closure with mothballing'. The variable-alternatives hierarchy, on the other hand, means that each higher order alternative may have different lower order alternatives, by type and number, available for modeling evaluation. The budget reduction model is an example, wherein some programs are evaluated for different levels of funding increase as well as decrease, while other programs are only compared for one or more levels of funding decrease. Fixed level hierarchical models are most often used to test political consequences of actions which would otherwise not even be considered possible alternatives. Variable level hierarchical models will typically represent decisional environments wherein specific alternative actions -- unique to each alternative -- have been identified as reasonable, and the results regarding the simulated effects of such decisions within the organization are desirable.

Collective Exhaustiveness. Whether in terms of the model of the environment constructed or the characteristics of the alternative actions to be simulated within that environment, all environmental and action oriented elements must be part of the model designed. A missing part of the environmental portion of the model would inaccurately monitor the impact of alternative decisions upon the organization being modeled. Similarly, the exclusion of an alternative action summarily precludes any means of understanding the impact of such an action as a potential solution to the problem identified.

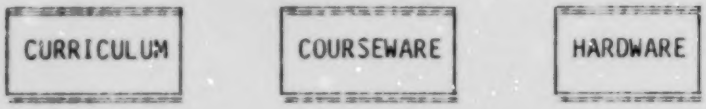
Mutual Exclusiveness. For a simulation model to be effective in terms of the alternate decisions identified, as well as efficient in terms of the process required for the comparison and contrasting of all available alternatives, each alternative action should be as discrete as possible, and not duplicate any other alternative under evaluation. The choice of any alternative should therefore represent a clear demand for the attributes of that alternative, and not simply a random selection between two (or more) alternatives which are identical in both focus and impact. For the hierarchical model, mutual exclusiveness also requires that separate subgroups of alternatives be identified, from which one and only one alternative will be selected as part of the final solution set.

Bounded Limits and Composite Impact. Hierarchical modeling, like many other types of mathematical models which are not hierarchical in design, relies upon numerical criteria to (1) assign value(s) for each of the alternative actions under consideration, and thereby (2) compute the composite worth for each of the various subsets of alternatives entered into the final solution for the system modeled.

SPECIAL CONSIDERATIONS FOR THE N-LATERAL DECISION SIMULATION MODEL

The MICROPIK™ formulation of a variable level, hierarchical model employs what might be referred to as an n-lateral modeling design. N-lateral modeling means that the mathematical representation of the model incorporates more than one system of decisional hierarchies. For the MICROPIK™ formulation, a total of three (3) such hierarchies may exist: (1) the curriculum objectives and instructional activities hierarchy, (2) the courseware packages hierarchy, and (3) the hardware systems hierarchy.

Conceptually, these hierarchies and their decisional interrelationships, can be viewed as follows:



| <==========> |

Mission
provide criterion measures related to curriculum requirements, student learning needs, and courseware content and process -- identifying the linkage between teaching needs and the extent to which courseware will satisfy these needs

| <==========> |

Mission
provide criterion measures related to courseware execution requirements and hardware support -- identifying the linkage between software materials and hardware equipment resources

| <=======> | ..... | <======> |

Mission
provide criterion measures related to special population needs (e.g. handicapped), special teaching requirements (e.g. graphics) and the hardware support necessary to effectuate the satisfaction of such needs -- identifying the linkage between co-curricular requirements and specialized equipment resources

The trilateral formulation of a hierarchical decisioning model requires two further considerations related to the preparation of the solution alternatives and the criteria which will support the comparing and contrasting of these alternatives.

Mutual Inclusiveness. The MICROPIK™ formulation of the hierarchical, multiple alternatives model (MAM™) requires a significant change in the way the

model evaluates decisional alternatives for the 'courseware' sectional of criterion measures. Since it can be reasonably assumed that more than one courseware package might be required to satisfactorily address learning needs, and such packages may contain elements which are similar to each other (thus violating the issue of mutual exclusiveness mentioned in an earlier section), any decisioning model must allow for mutual inclusiveness in this situation. That is, the model should have the ability to select a group of courseware packages which, collectively, best address the specific learning needs found in the curriculum sectional submatrix.

Lateral Submatrices. The trilateral formulation requires three (3) criterion sectionals: curriculum, courseware and hardware. For the model itself, this represents three submatrices of values, side-by-side or laterally configured, and moreoever requiring some method for mathematically connecting the values of one with each of the others (as described in each of the 'missions' identified in the preceding figure). These lateral submatrices are portions of what is known as the coefficient matrix, a mathematical formulation which contains the criteria related to each of the curriculum, courseware and hardware sectionals. As we will see in a later section of this paper, this coefficient matrix stores the values of the linear equations and inequalities which provide the comparison and contrast design for the multiple alternatives modeling™ formulation of the MICROPIK™ model itself.

DESIGN AND LINKAGES FOR LATERAL SUBMATRICES

Technically speaking, the use of lateral submatrices for multi-system hierarchical (decision) models requires a technique for (1) transfering data between the different hierarchical decisional systems and (2) reporting information from each decision performed in one system to all others as such comparison and contrasting activities are effectuated. This is no simple task, though it is accomplishable, and must be assured.

Two additional submatrices are necessary to satisfy these data/information transfer needs: a 'control' vertical submatrix and a 'slack' lateral submatrix.

For reasons of scope and time limitations, this section of the paper briefly illustrates the use of the control verticals and slack laterals.

> Note: The reader is invited to contact the author in early 1985 for a copy of a new paper, currently under development for the United Nations Educational, Scientific and Cultural Organization (UNESCO), which speaks in greater detail to the issue of submatrices for internal decisioning control and slack variable storage.

Control Variables. Control variables are stored in that vertical submatrix known as the control vertical, and provide the model with the ability to identify specific data and/or information for transfer between the criterion submatrices. As a brief example, consider the difference equation:

$$3C^1 + 5C^2 - 2C^3 = S^0$$

where the value(s) of C^1, C^2 and C^3 are restricted to either '0' or '1', i.e. '1' is C(i) exists, and '0' otherwise. Therefore,

$$C^1=1 \text{ and } C^2=0 \text{ and } C^3=1 \text{ ===> } S^0=1, \text{ since } (3*1 + 5*0 - 2*1) = 1.$$

By transposition, this equation can be reformulated into:

$$3C^1 + 5C^2 - 2C^3 - 1S^0 = 0.$$

This suggests that the linear system of equations:

$$3C^1 + 5C^2 - 2C^3 = 0$$

$$1C^1 + 1C^2 + 1C^3 - 1S^0 = 0$$

will accomplish that same transposition, but more importantly, will constantly update the value of the S(0) variable -- called a slack variable -- as the values of the C(i) variables change. The second systemic equation, the control vector (with all coefficients of value ± 1), is contained within the special vertical submatrix known as the control vertical submatrix. It is the function of

this submatrix to provide the means by which data/information is transferred throughout the decisioning model as needed. For this reason, this particular submatrix is also known generally as the information management system (IMS) submatrix.

Slack Variables. All slack variables are stored in a lateral submatrix, called simply the slack lateral submatrix. It is the function of this portion of the decisioning model to provide storage for those 'internal composite' measures generated in the three criterion submatrices, and allow access and retrieval by the IMS (control) submatrix. For this reason, the slack lateral is known generally as the management information system (MIS) submatrix. Slack variables store intermediate computational results (usually sums and differences) which can be later used for (1) other numerical calculations, as well as (2) logical comparisons by way of internal tautalogical controls.

Tautalogical Linkages. A tautalogy, typically of the "if ... then ..." framework, allows for not only the access to, and retrieval of, data and information within a criterion based decisioning model, but also provides a basis for internal decisionmaking related to logic. This internal logic control can be throught of in three contexts: (1) general inclusion, wherein decision alternatives are identified as logical results of final selection, that is, these alternatives may potentially vie for inclusion as a member of the final solution set; (2) specific inclusion, wherein certain alternatives are linked to other specific alternatives, such that an 'effect' of one alternative being entered as part of the final solution automatically signals the inclusion of another alternative as part of the solution also; and, (3) specific exclusion, which is the reverse of inclusion, that is, the choice of one alternative as solution automatically signals the exclusive of another alternative from further consideration.

General inclusion may be viewed, through the use of control and slack variables as follows

		C^1	C^2	C^3	S^0		
GENERAL INCLUSION	Unconditional A,B,C elements of concept X	+1	+1	+1		$\geq$	+1

The above example simply states that of the alternatives, C(i), i=1,...,3, at least one alternative must be resident in the final solution set.

Specific inclusion requires each of three special cases to be available for modeling unconditional inclusion (an alternative will be part of the solution), contingency allowance (an alternative may be part of the solution if another alternative is selected as solution), and conditional control (an alternative will be part of the solution if another alternative is selected). The possible combinations and permutations of these settings are illustrated below in terms of the necessary control and slack variables.

		C^1	C^2	C^3	S^0		
SPECIFIC INCLUSION	Unconditional						
	A exists	+1				=	+1
	A and C exist	+1		+1		=	+2
	Contingency Allowance						
	If A and B then C (possible)	+1	+1		-1	=	0
				-2	-1	$\leq$	0
	If A or B then C (possible)	+1	+1		-1	=	0
				-2	-1	$\leq$	0
	Conditional Control						
	If A then B	+1	-1			$\leq$	0
	If B then A	+1	-1			$\geq$	0
	B If and only If A (If A then B and If B then A)	+1	-1			=	0
	If A and B then C	+1	+1		-1	=	0
				+1	-1	$\geq$	-1
	If A or B then C	+1		-1		$\leq$	0
				+1	-1	$\leq$	0

Specific exclusion is similar to inclusion (above), but requires a different control over the transposition form of the control variable. For the novice modeler, the use of exclusion is linked to the belief that, while some alternatives may not be considered as potential solution members, e.g. due to political, cultural and/or religious values, the impact of the alternative's influence upon the remaining parts of the model is important. With specific exclusion, the criterion values of a specifically excluded option are available for the model's analysis, though not for consideration as a potential decision.

The specific exclusion formulation for control and slack variables may be viewed as follows·

		C^1	C^2	C^3	S^0		
SPECIFIC EXCLUSION	Unconditional						
	A does not exist (Not A)	+1				=	0
	Not A and Not C	+1		+1		=	0
	Contingency Allowance						
	If A and B then Not C (possible)	+1	+1		-1	=	0
				-2	+1	$\geq$	0
	Conditional Control						
	If A then Not B	+1	+1			$\leq$	+1
	If A and B then Not C	+1	+1		-1	=	0
				+1	+1	$\leq$	+2
	If A or B then Not C	+1		+1		$\leq$	+1
			+1	+1		$\leq$	+1

The subtlety associated with contingency allowance versus condition control (viz. demand) is significant, and bears continued discussion.

Demand Versus Allowance. Decision modeling attempts to control two types of decisional environments. The first, typically referred to as the demand environment, signals that relationships between and/or among optional alternatives are such that a judgement of the attributes of one decisional alternative automatically impacts another alternative not currently being directly considered. On the other hand, alternatives linked in an allowance environment may or may not be further considered as options, based upon a related alternative's inclusion as a solution; that is, other criterion analyses are still required.

MICROPIK™ - A BILATERAL, HIERARCHICAL MODELING FORMULATION

In order to create a functional decisioning model which would comprehensively compare and contrast the curriculum requirements of any particular course of study with potentially usable computer courseware and microcomputer hardware, two different approaches had to be considered. The first, called the trilateral formulation, required the construction of three (3) sets of lateral submatrices, related to the evaluation requirements of the curriculum, courseware and hardware, respectively. The second approach and subject of this paper, the bilateral formulation, requires only two (2) sets of lateral submatrices, one for curriculum evaluation needs and the other as a shared framework for courseware and hardware assessment.

This does, in no way, suggest the obsolesence of the trilateral model. In fact, the trilateral model is still a most viable strategy for hierarchical decision modeling which attempts to simulate alternative decisions in settings which might be considered inordinately complex. For example, MICROPIK™ modeling on a bilateral level is recommended when a single curriculum is involved, and the courseware/hardware combination options are limited. However, if more than one curriculum was under evaluation, or the specific needs of several diverse populations of students were incorporated within the model, or several courseware/hardware combinations were entered as part of the simulation -- then a trilateral formulation would almost certainly be the preferred approach.

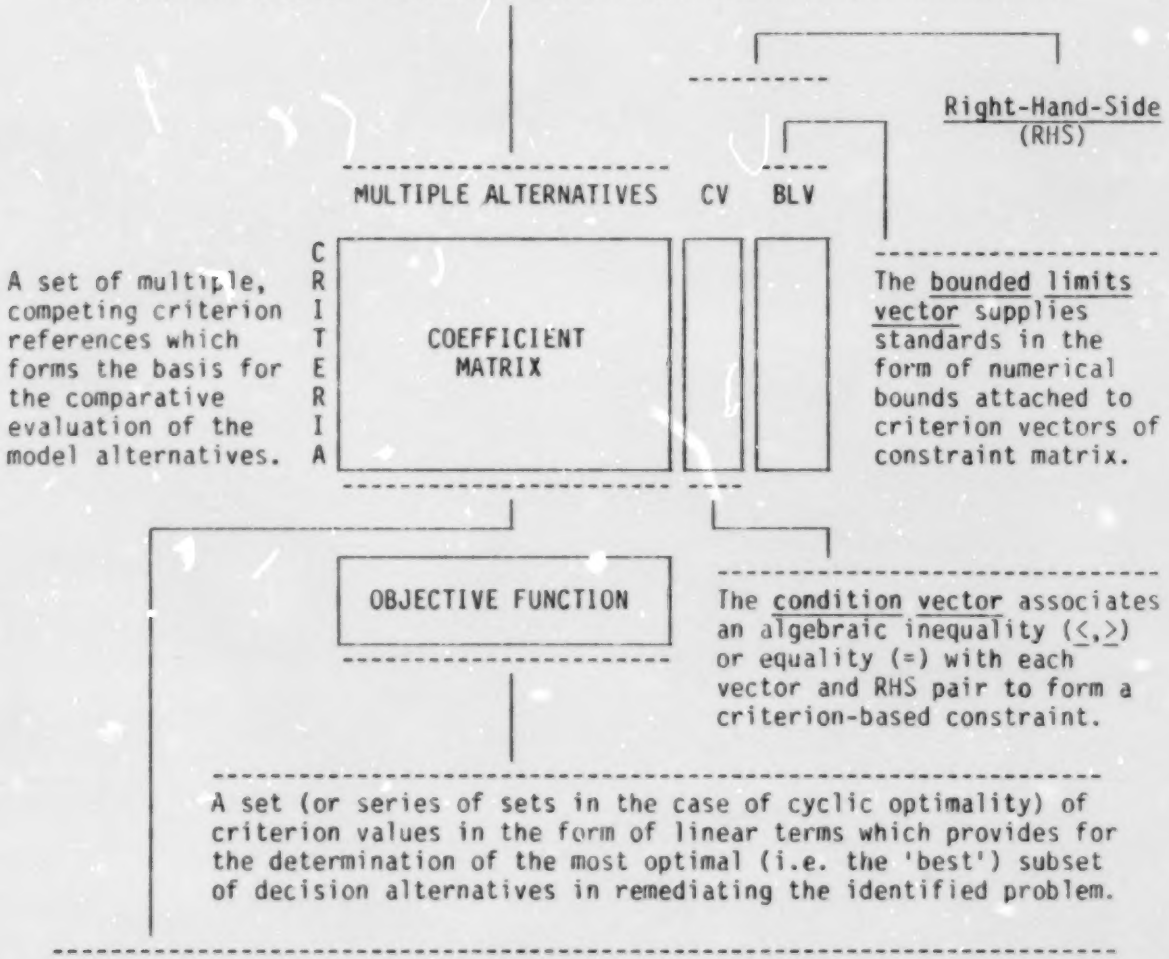
As a bilateral revision of the original hierarchical version of the Multiple Alternatives Modeling™ formulation (Wholeben, 1980; 1983), significant diversification of the MAM™ framework was necessary. To better understand this modification, and thus the MICROPIK™ formulation itself, we will briefly examine the original modeling framework for the Multiple Alternatives Model™.

The MAM™ Formulation. The original formulation, initially developed in 1978 for targeting elementary schools for closure in a large, midwestern city (see: The Design, Implementation and Evaluation of Mathematical Modeling Procedures for Decisioning Among Educational Alternatives (1980)), utilized a simple system

of simultaneous (algebraic) linear equations and inequalities for comparing various solution alternatives, by number and name (i.e. the various schools which might be closed).

Generically, this model is viewed, with annotations, as follows:

A collectively exhaustive set of mutually exclusive decisions which have been designated as comprehensively reasonable reactions to the problem situation identified; and from which a subset of decision alternatives may be drawn to construct the final solution set.


Right-Hand-Side
(RHS)
MULTIPLE ALTERNATIVES
CV
BLV
CRITERIA
COEFFICIENT MATRIX
A set of multiple, competing criterion references which forms the basis for the comparative evaluation of the model alternatives.
The bounded limits vector supplies standards in the form of numerical bounds attached to criterion vectors of constraint matrix.
OBJECTIVE FUNCTION
The condition vector associates an algebraic inequality (≤,≥) or equality (=) with each vector and RHS pair to form a criterion-based constraint.

A set (or series of sets in the case of cyclic optimality) of criterion values in the form of linear terms which provides for the determination of the most optimal (i.e. the 'best') subset of decision alternatives in remediating the identified problem.

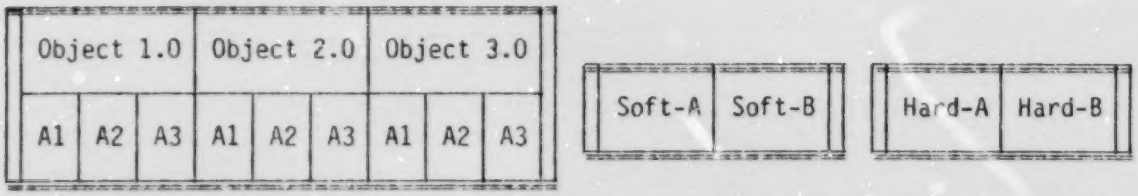
The vector portion (coefficients of the left-hand-side) which denote for each of the modeled alternatives (viz., the dependent variables), the value of each particular criterion's measure or influence (viz., the independent variables) related to that same particular alternative. Thus, the coefficients of each term in the linear inequalities represent the specific criterion measure for that particular term (i.e. alternative).

The maior modifications to this model involved a total restructuring of the coefficient matrix into partitioned submatrices. We will explore this change,

and the effects upon the use of the model for decisionmaking, after viewing in detail the structure of the alternatives vector for the MICROPIK™ formulation.

The Alternatives Vector. The framework of the MICROPIK™ formulation is best understood initially through anexamination of the alternatives vector, that is, that part of the model which defines which alternatives are available for evaluation, and from which a select subset will be identified as the final solution. Exploring the trilateral formulation first, we view the model as containing three separate sets of alternatives, one for each of the curriculum objectives, alternate courseware packages, and necessary hardware systems.

For example, consider the situation where three classroom activities for each of three curricular objectives are being compared with two software packages and two hardware units. The mission of this comparison might serve to detect which classroom activities are supported by which software package and which hardware system. The model would attempt to determine the best software and hardware combination purchase which would in turn maximize the satisfaction of the greatest number of classroom activities for student learning. Such an exampled situation might be illustrated as follows:



For a general perspective of the decisional environment being modeled, we might view the above figure, reformulated as follows:

Hardware Alternative-j (j=1,...,n) ==> Type of Microcomputer					
Software Alter-s (k=1,...,s,...,K)			Software Alter-t (k=1,...,t,...,K)		
Object 1.0	Object 2.0	Object 3.0	Object 1.0	Object 2.0	Object 3.0
Range of Possible Activities for 1.0	Range of Possible Activities for 2.0	Range of Possible Activities for 3.0	Range of Possible Activities for 1.0	Range of Possible Activities for 2.0	Range of Possible Activities for 3.0

This hierarchical setting (above) displays the decisional environment in a "top-down, hardware dependent" framework. In such a setting, available hardware units are compared with potential courseware packages which have been identified to support, in some varying detail, the objectives of curricular elements which are defined by a range of possible classroom activities.

An alternative formulation in a hierarchical setting might view the decision environment as a "top-down, curriculum dependent" framework:

Learning Concept Alternative-j (j=1,...,n) ==> Instructional Goal																	
Classroom Activity #1						Classroom Activity #2						Classroom Activity #3					
Soft-A		Soft-B		Soft-C		Soft-A		Soft-B		Soft-C		Soft-A		Soft-B		Soft-C	
H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2

Here, learning concepts (curricular goals) are identified and delineated into various classroom activities. The classroom activities are matched for their

varying support from alternative courseware packages, and the hardware units for which these packages would be executable.

From the above two conceptual hierarchical frameworks, a decision model was designed which would incorporate all aspects of cross-comparison (viz. curriculum with courseware, and courseware with hardware) into the alternatives evaluation process, and in addition better associate the evaluation of alternatives mathematically. The result of this design objective was the bilateral modeling formulation, alluded to earlier, and conceptualized as follows:

Object 1.0			Object 2.0			Object 3.0		
A1	A2	A3	A1	A2	A3	A1	A2	A3

Hardware Alternative-s (s=1,...,S)
Software Alternative-t (t=1,...,T)

Returning to the figure which conceptualized the original MAM™ framework, this bilateral formulation requires the partitioning of the 'coefficient matrix' into two separate, though mathematically linked, entities: (1) a coefficient submatrix which contains evaluation data/information regarding the curriculum being compared with computer materials and equipment, and (2) a second coefficient submatrix, laterally configured, which contains additional evaluation data/inoformation related to the courseware and hardware. Subsequently, another submatrix, this one vertical in orientation, will be necessary to relate the 'curriculum coefficient submatrix' with the 'courseware/hardware coefficient submatrix', mathematically.

Such a bilateral MAM™ orientation for MICROPIK™ modeling might pose an alternatives vector for comparing desired classroom activities with available computer resources as follows, where identical types of activities support the various curricular objectives·

Object 1.0			Object 2.0			Object 3.0		
A1	A2	A3	A1	A2	A3	A1	A2	A3

Hardware-A		Hardware-B		Hardware-C	
SW-1	SW-2	SW-1	SW-2	SW-1	SW-2

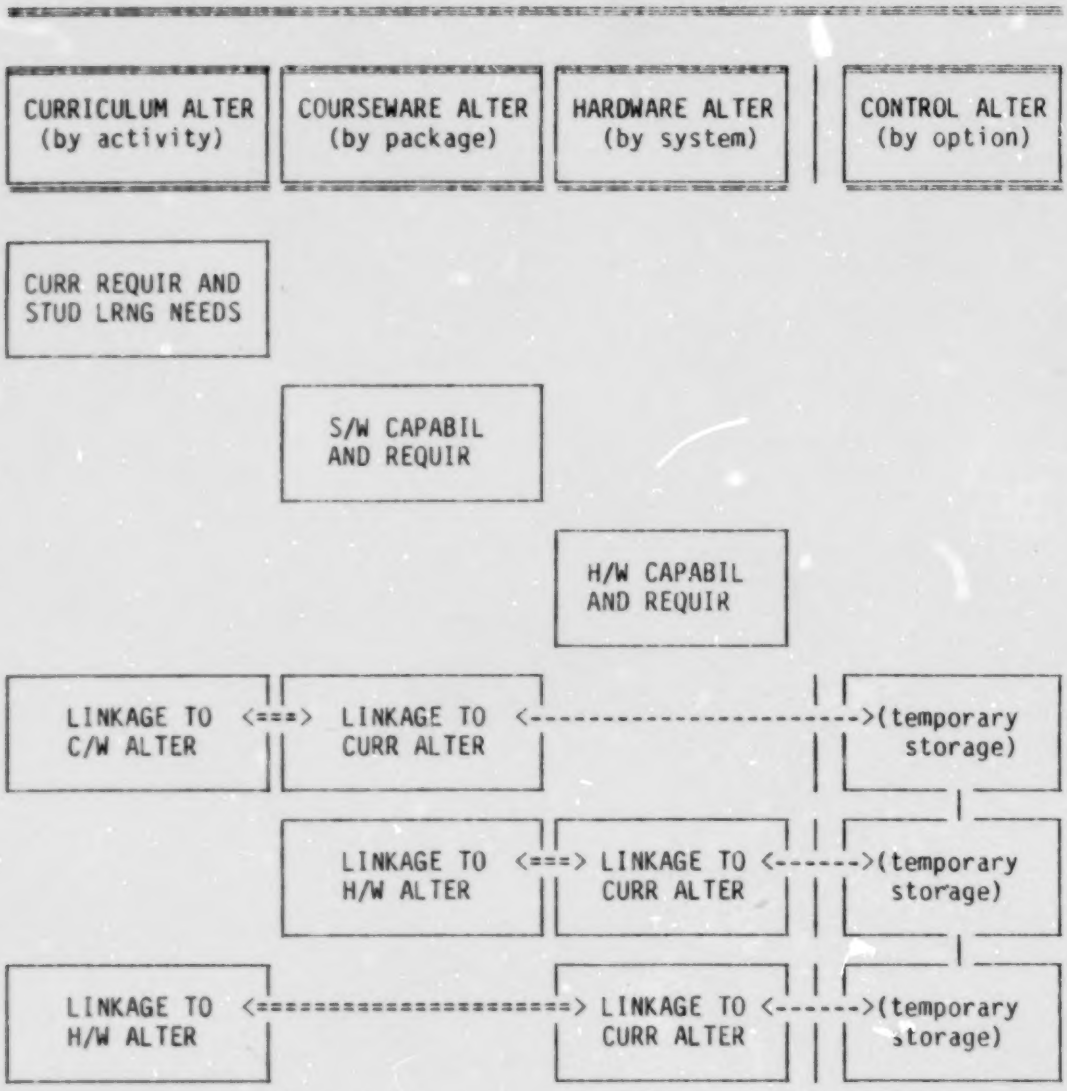
Alternatively, a diversified curriculum model might be necessary in the situation where either (1) different types of curricularly related activities are being evaluated, or (2) several different curricula are under evaluation, simultaneously, in order to ascertain which software/hardware combinations support the best, overall mix of curricular objectives' satisfaction. A vector of decisional alternatives for such a modeling mission might appear as:

Object 1.0			Object 2.0			Object 3.0		
A1	A2	A3	A4	A5	A6	A7	A8	A9

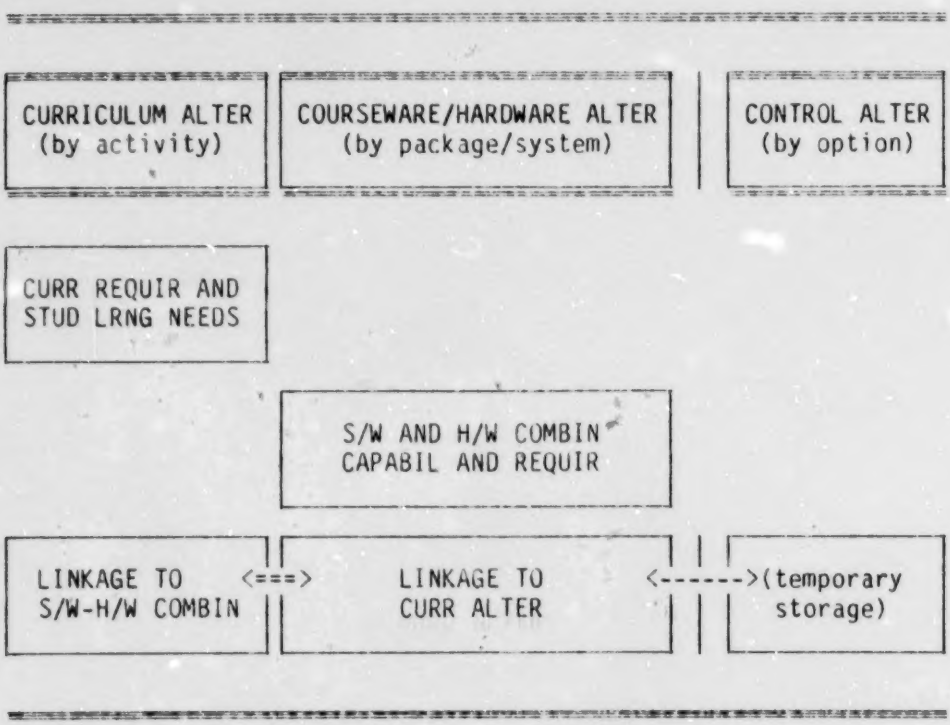
Hardware-A		Hardware-B		Hardware-C	
SW-1	SW-2	SW-1	SW-3	SW-4	SW-5

With the structure of the alternatives vector in mind, we can now proceed to a more detailed albeit brief discussion of the MICROPIK™ formulation, and the structure of the MICROPIK™ coefficient matrix, as a whole.

Trilateral MICROPIK™ Structure. To better understand how a trilateral formulation of the hierarchical decision model might structure the various criterion based interactions, the following chart of structured interactions is provided. Each set of lateral submatrices reflect portions of the coefficient (viz. criterion values) matrix which, when related through tautalogical control, perform a variety of specialized internal decisioning functions.



Bilateral MICROPIK™ Structure. The degree to which a bilateral reformulization of the trilateral model simplifies the number and type of interrelated data/information linkages can also be seen via the following chart of structured interactions.



Specific Criteria Needs. To fulfill the individual evaluation roles for each of the curriculum, courseware and hardware sectionals (viz. lateral sub-matrices) specific criteria is necessary which will (1) assess the relative importance and integrity of each instructional objective, courseware package and microcomputer unit, and in addition (2) evaluate the best cross-sectional mixes for matching courseware and hardware system with the widest, possible range of instructional objective(s) satisfaction.

Note The majority of this section has been excerpted from the NWREL Research Report No. 73, MICROPIK: A Multiple-Alternatives, Criterion-Referenced Decisioning Model for Evaluating CAI Software and Microcomputer Hardware Against Selected Curriculum Instructional Objectives (Portland, Oregon; NWREL, June 198[illegible].

To fulfill the stated premises of the MICROPIK™ model in determining the appropriate microcomputer hardware and software in terms of stated instructional

requirements, the various sections of multiple alternatives described in the previous topic must be evaluated across various competing criteria. As was mentioned in a previous section, the MICROPIK™ decisioning model may require a total of six 'types' of criterion formulations: three to address the intra-relationships existent within each of the three sectional areas of curriculum, software and hardware -- to allow cross-comparisons of the various alternatives within each of the main alternatives' sections. Two additional criterion sets are required to measure those inter-relationships which will need to be controlled between the sections of curriculum versus software, and software versus hardware. It is assumed, that the third possible bi-sectional criterion set which would relate curriculum versus hardware can be based upon the trichotomous inference resulting from the first two bi-sectional comparisons. Finally, a criterion set will be reserved for an overall, trisectional evaluation of curriculum v. software v. hardware' inter-relationships.

[Generic Criterion Indices]

As with all planning and development activities, the modeler will find the utilization of a 'philosophical' model most helpful in identifying and defining 'types' of criteria which may prove useful in discriminating between the multiple alternatives. This is of greater importance within the CAI-MAM framework due to the complicated relationships both <u>between</u> the three general alternative sections (curriculum, software and hardware) as well as <u>within</u> each of these general sections. Before a general listing and discussion of more specific criterion indices which will be of some benefit to the MICROPIK™ modeler, a more genus-oriented discussion of criterion-type will be presented.

Three categories of generic criterion indices seem to exist for all problems of evaluation and decision-making when dealing with multiple alternatives:

[1] index of contextual need based upon performance;

[2] index of relative worth or value; and

[3] index of general resource or expenditure.

The index of contextual need based upon performance is itself a relative comparison between the measured states of perceived need, current performance or use, and observed demand. Such contingencies as where demand is greater than need suggest either an unrealistic understanding of the enterprise, or an equally unrealistics understanding of the characteristics of whatever is declared 'in demand'. Of course, a contingency of need greater than demand might also point to a lack of understanding of the context within which the organization exists. Indicators such as might indicate waste (demand greater than performance and/or need) or intervention (need greater than performance) must also be addressed in some fashion as part of the contextual need set of criteria.

The index of relative worth or value is often more easily modeled into an evaluation framework due to its more 'esoteric' issues of: effectiveness, efficiency and satisfaction. To be effective, whatever is performed (or in our case, selected) must "do the job". To be efficient, the selected alternative solution must do the job as quickly as possible, and within the stated operational limits of the enterprise (or less). And to be considered satisfactory, the solution must portray 'good' feelings on the part of all parties involved; or at the least, be consistent in this regard.

The index of general resource or expenditure is a more direct relating of alternatives to those elements of capital, revenue and/or expenditure which might be required in the final implementation of the selected alternative. Such resources as time, space, facility, personnel, cost, supplies and materials, and equipment -- will all be a potential part of this particular criterion set.

[Reference and Source]

Having identified and defined the criterion measures which will be utilized within the MICROPIK modeling of the CAI software and hardware decisioning problem, the modeler must next turn attention to determining 'what' will be measured in order to provide a quantified value based upon the construct of each of the variables or criteria defined. In this context, the 'what' of criterion measurement is known as the criterion reference, that is, what the modeler refers to in order to obtain a valid measure of the criterion point identified. Then of course, the modeler must determine 'where' such a measure will be available and/or from 'who' if other people must be involved. The 'where' and 'who' in this context of criterion measurement is known as the criterion reference source or data-point source. References will always involve a determination of validity of the particular measure, while sources will always necessitate an analysis of reliability. The reader must recognize, that potential nonreliability can related to the people involved, the place or time of the measurement, and the procedure utilized in the measurement process -- that is, the who, where, when and how. The remaining interrogative adverbs of what and why relate more closely with the determined validity of the measured criterion point.

References may be categorized (loosely, I admit) into the three areas of: physical, definitional and synthetic. A physical reference or measure is one in which a fully acceptable tool of measurement is utilized to determine the value or weight of the reference involved. In science, degrees of temperature, miles of distance, and knots of wind velocity are acceptable determinants of their associated references (temperature, distance and wind velocity).

Definitional references are simple or complex transformations of physical measures in order to obtain a new datum to address a defined criterion which can not be measured directly. For example in the determination of school closures, a total of nine definitional criteria were designed and tested for their usefulness in discriminating between elementary school buildings in order to determine their reasonableness for operational discontinuance (Wholeben, 1980a).

Recall that synthetic measures are normally data points of perception or subjective judgement based upon personal opinion; and thus has all of the reliability problems associated with subjective bias. However, it must be reiterated, that synthetic criterion references are still very much an important 'source' of data for evaluation and decision-making. As is the case in all evaluation, the problem is seldom the intent; but too often the content and process used in carrying out that intent.

Specific criterion references for quantifying usable MICROPIK data input will generally involve the use of several procedures or tools. Measures related to the curriculum sectional must be demonstrative of not only the content and process of the various instructional activities, but also the relative importance and degree of duplication existing between these activities in the promotion of individual concept learning. Such criteria as the degree of achievement, amount of time required to implement the particular activity, and amount of retention by student will be directly related to the references of performance testing via a number of valid items or problems, clock time, and some form of longitudinal testing utilizing similar problem item, respectively. Criteria related more directly to opinion or perceptual judgement on the part of students and teachers concerning the various instructional activities will be referenced by (for example) some number of statements which describe an opinion concerning some aspect of the activity, and via a survey format gain a measure of 'degree of agreement' by the respondent with respect to the particular individual items.

Gaining responses to the same item (via survey techniques) from two different though related populations is a direct example of how synthetic measures can be transformed in a definitional composite, much as the physical illustrations earlier in this section. Given responses from both students and teachers to an identical item on two different surveys:

"Learning how to spell using a 'spelling bee'
is better than using the class workbook."

Obviously, high agreement on the parts of both teachers and students is preferred. However to control not only for degree of agreement to the item, but also for the criterion identified as 'degree of consistency' between teacher and student responses, the following transformation may be utilized to provide a definitional measure of consistency:

MINIMIZE | (teacher response mean) - (student response mean) |

where this formulation controls for between-groups consistency of response. A similar method for controlling the measure of consistency 'within-groups' is to utilize the standard deviations computed for each of the populations; and formulated as

MINIMIZE | (teacher response standard deviation) |

and

MINIMIZE | (student response standard deviation) | .

Measures of degree of achievement by students using different types of CAI software will be referenced similarly to those ideas expressed above for the instructional activities. Perceptual measures (synthetic) can also be referenced via the administration of valid questionnaires concerning feelings toward the experience of executing the various packages.

Criterion to permit the evaluation of the components of the hardware sectional will normally fall within either physical or synthetic references. Such physical references as clock speed of the CPU (central processing unit) in megahertz (MHz) equivalents (i.e. how many millions of cycles per second are performed), and of internal expansion capability in bytes of storage equivalents (a byte being a single character of input as defined by either an alphabetical character, a numeral (single-digit) or a special character (#,%,*)) -- provide readily understandable (?) illustrations. More subjective judgements are also

possible concerning the 'esthetics' of the terminal face, or the quality of the printer. A survey format of the 'check-list' variety is a useful tool in gaining such information.

Through our addressing the issue of criterion references (that is, the 'what' of our needed criterion measure), we have paralleled the issue of reference source, or from where (whom) and how such information can be found (or be forthcoming). The data for the curriculum sectional will come from students, teachers and parents -- depending upon the type of criterion being measured. The process may involve the use of observation, a pencil-and-paper questionnaire, standardized achievement test, or a structured interview. Information for the criterion to permit comparable evaluations of the software packages will be measured in a similar fashion. Additional data for the software sectional however can also be gathered via the "dead data" technique of reviewing brochures and records, as well as the more "live data" techniques of observation and survey response.

Much of the information required to quantify the criteria of the hardware sectional will be found via the "dead data" search. Manufacturer's brochures and available technical product reports provide such reference sources. Journal articles may be also helpful; and so also the findings of such periodicals as the 'Consumer's Report'. Whatever reference and source the modeler utilizes for the generation of data points, the cautions concerning reference validity and source (procedureal) reliability must be ever present in the modeler's consciousness.

Except in more complicated MAA models related to the matching of instuctional activities to available CAI software and compatible hardware, the criterion reference for modeling both the curriculumsoftware and software-hardware sectional will that of 'availability' of the appropriate software package or hardware unit. The source of course will always be the manufacturer and distributor.

[Scaling and Measurement]

Scaling refers to the type of numeric which will represent the measure of the defined criterion reference; and may be one of four types: nominal, ordinal, interval or ratio. The reader is referred to any standard tests and measurement, or introductory statistics text for operational definitions of these scaling types. As a summary however, the types may be distinguished as follows (apologies in advance to those measurement specialists and/or statisticians among the readers)

[1] the nominal scale is pure categorical classification measure of group distinction only; the relationship between groups is one of difference without reference to either direction or extent; examples are sex (male v. female) and minority (minority v. non-minority);

[2] the ordinal scale is one-step-up from the nominal type in that direction or order is now distinguishable for different responses or measures; however, the extent between these directional differences is unknown, and provides a classic potential for interpretative error; examples are assigned ranks and achievement grading as defined by 'excellent v. good v. fair v. poor ;

[3] the interval scale is an improvement upon the ordinal type in that both direction and extent (or degree) are now distinctive under interpretation; the intervals between each of the unique measurement points are equal throughout the scale; examples are age expressed in whole years, and off-spring expressed in whole units (normally); and,

[4] the ratio scale exhibits all qualities of the interval type, and in addition allows infinite divisions between any two points on the scale's continuum; in fact, the ratio scale is the only real continuum since it provides one of the most finest of possible approximations available; for example speed expressed in cycles-per-second units.

The measure (of course) is simply the numerical quantity which results from use of the scale in determining the value of the criterion from the selected cri-

terion reference.

The reader should note, that different measures (and often different scalings) can take place with respect to the same criterion reference -- or different references with respect to the same criterion identified. Measures such as these are often the result of a survey of opinion which attempts to gain insightful data concerning various issues of interest or aspects of current endeavor.

The MICROPIK™ model will accomodate any of the scaling types dependent upon the intent of measure (indentified and defined) being sought. Availability of certain software and hardware units will often be identified as a '1' (availability = yes) or a '0' (availability = no); and therefore uses a nominal scaling type for final measurement. Presenting a group of respondents with a list of instructional activities concerning the satisfaction of a specific curricular objective, and asking them to rank-order their importance in promoting the learning defined by that objective, results in the ordinally-scale measure of ranks (1 = most important, 2 = next most important, ...). The interval type of scaling is assumed with such extended continuum frameworks as the 6-point agreement continuum. And finally, the ratio scale is most usable with the more physical measurements associated with system specifications, cost of various software and/or hardware units versus the salaries of additional classroom teachers, and achievement performance measures on the part of the students.

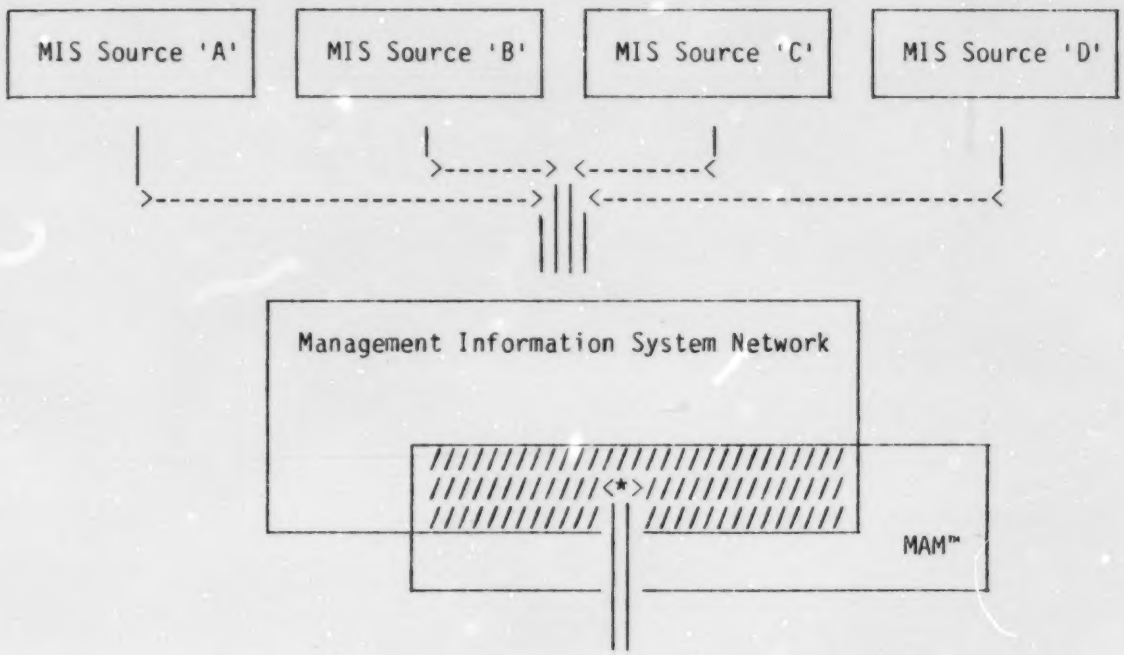
Excepted from: NWREL Report No. 73, June 1982, pages 31-58.

STAGE V™ MODELING - THE FUTURE FOR DECISIONING SIMULATIONS

Decision modeling has progressed, in the form of the multiple alternative modeling™ formulation through a total of four (4) stages since its inception in 1978. Stages I and II witnessed the change from a singular alternatives model

for simple policy modeling to the multiple alternatives formulation for implementation modeling. Stages III and IV saw the model advance into hierarchical modeling formulations, simple hierarchies for such problems as graduated budget reductions and multiple hierarchies as in the MICROPIK™ formulation.

Stage V (viz. stage '5') modeling, now under development, will allow for what we might call continuous decision modeling, or CDM. Conceived as a ready source of information based upon all available data in a structured management information system, CDM might appear as found in the following figure.



'Stage V' Simulation Modeling
[Continuous Decision Modeling (CDM)]

In the 'continuous' setting, the standard MIS framework would have the necessary system processes to supply information on potential decisioning needs, continuously, based upon the variable atmosphere of the fluid, transactional environment which the MIS serves. The decisionmaker would simply have to spe-

cify the criteria to be utilized in the simulation process, whether any specialized alternatives in addition to the conventional decision alternates should be considered, and other changes to the constraints which would guide the decisioning process, itself.

The Stage V modeling framework requires that a generic model of the decisionmaking process be designed, and in addition, that the model be constructed so that its access and retrieval of data from the MIS (i.e. the IMS strategy) would automatically structure the data as input to the generic decisioning model. With the advent of artificial intelligence, there is reason to believe that highly specialized programs might also have the ability to construct likely alternatives based upon certain parametric considerations.

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